Atmospheric Radio Noise*

By F. HORNER, M.Sc., A.M.I.E.E.

IN present-day conditions the most serious sources of interference to reception on many frequency bands are man-made signals from other transmitters, and noise from electrical apparatus. Nevertheless, natural noise from lightning flashes in thunderstorms is still important on some frequency bands in many parts of the world. It is necessary to know the intensity of this atmospheric noise to decide on the transmitter power which is required to operate a given service.

Properties of Atmospherics

The best-known feature of a lightning discharge is the intense stroke to ground, with a peak current of the order of 20,000 amps., and this is the main source of noise at the lowest frequencies (below 30 kc/s). The noise consists largely of impulses of short duration from these ground strokes. At higher frequencies the ground stroke is less important, and the noise seems to originate in smaller but more prolonged discharges in the thundercloud. The difference between the two types of noise can be seen in Fig. 1, in which the upper and lower traces show atmospherics

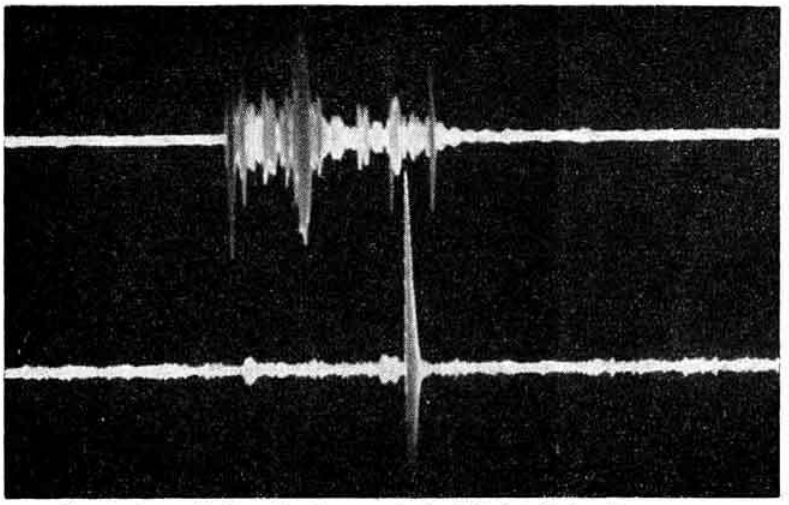

Fig. 1. Atmospheric noise from a single lightning flash. Upper trace —11 Mc/s; lower trace—6 kc/s; bandwidth about 250 c/s.

from the same lightning flash, recorded simultaneously at 11 Mc/s and 6 kc/s, both in a bandwidth of about 250 c/s. The duration of the h.f. burst was 100 milliseconds. The 6 kc/s pulse probably originated in a stroke to ground four miles away and the 11 Mc/s noise in the cloud discharges which preceded the ground stroke. Noise is impulsive at all frequencies but at high frequencies it tends to become similar to thermal noise if there are contributions from a large number of storms.

Although the noise has been depicted in Fig. 1 with about the same amplitude on both frequencies, the peak field at 6 kc/s is actually much greater than that at 11 Mc/s—200 mV/m compared with 0·4 mV/m.

In radio communication problems, two types of information on noise are required. The first is the distribution of noise intensity over the surface of the world, and its variations with frequency, time of day, and season; the second is the type of noise structure—whether it is impulsive, as shown in Fig. 1, or more smooth, like thermal noise in valves.

Distribution of Noise Over the World

The parameter adopted for describing geographical and temporal variations is the noise power, averaged over a period of approximately one hour. All the available data have been expressed in this form and collected into a report published by the International Radio Consultative Committee (C.C.I.R.). [1] This report contains a series of charts for different seasons and times of day, an example of which is reproduced in Fig. 2. On these charts are plotted contours showing the noise power available from a short vertical aerial, at 1 Mc/s, expressed in decibels above the thermal noise from the aerial. High noise levels are seen to be encountered in the equatorial land masses and low levels in polar regions.

To obtain noise intensities at other frequencies from that at 1 Mc/s two series of curves are used. Fig. 3 shows that to be used during daylight at the receiving location and there is a similar one for dark conditions. The noise is related to the intensity at 1 Mc/s as deduced from the charts. An indication is also given of the noise from the galaxy and the appropriate level of man-made noise at a good receiving location. This level is, of course, subject to wide variations depending on local conditions.

The higher curves in Fig. 3, which apply to places near the main thunderstorm centres, show how the noise power decreases with increase in frequency. Above 10 Mc/s the power decreases rather rapidly because the area of the world from which regular ionospheric propagation is not possible increases with frequency. In the middle frequency range ionospheric absorption reduces the noise levels at places well removed from the main thunderstorms, and the atmospheric noise is negligible compared with man-made noise on most of these sites.

The C.C.I.R. noise data are provisional and more measurements are being made to check them. In particular, equipment has been developed in the United States for the automatic measurement of noise power on eight frequencies, and it is hoped that this equipment will ultimately be installed at 50 stations.[2]

Noise Structure

Noise structure is a term used to describe the rapid fluctuations in amplitude in a short sample of noise—perhaps only a few seconds long. A means of describing this structure is required in studies of the interference to different types of radio service. For example, noise containing a few large peaks may interfere seriously with a service using pulse modulation, while a smoother type of noise of the same overall power would not.

A partial description of the noise structure can be given in terms of the fraction of time, in a short sample, that the amplitude exceeds different voltage levels—this shows whether any large peaks are present. Alternatively, the

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number of peaks which exceed different voltages may be counted. A full description must, in addition, give an indication of the lengths of the noise pulses and of the intervals between them. Methods of carrying out such observations have been developed, and it is hoped that as a result all the information on noise required by engineers will become available.

Examination of the noise structure, particularly at low frequencies, is also useful in studying the reflecting properties of the ionosphere. If an atmospheric is displayed on a cathode ray tube it is often possible, particularly at night,

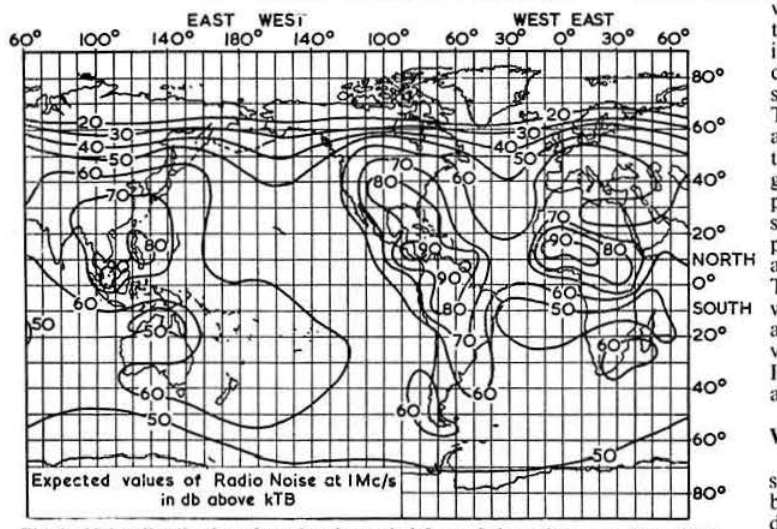

Fig. 2. Noise distribution chart for the period June, July and August, from 16.00 to 20.00 L.M.T.

to distinguish the part received by ground wave propagation, followed by the one hop ionospheric wave, the two hop wave, and so on. As many as 40 successive "echoes" have sometimes been recorded. An example of a waveform with 17 echoes is shown in Fig. 4. From the measurement of the time intervals it is possible to deduce both the distance of the flash and the effective height of reflection of the waves. The amplitudes of the echoes also furnish information about the reflecting properties of the ionosphere.

Location of Noise Sources

The problem of describing the noise would be simpler if we knew more about the lightning flashes in which it is generated. It would be useful to know the precise nature of an atmospheric, at any frequency, from a single discharge. Such observations are best made at close range to eliminate the effects of propagation. Records such as those in Fig. 1 provide information about the atmospherics, but it is necessary also to know the distance of each recorded flash. At ranges of only a few kilometres this can be deduced from the time-delay between the visual flash (or the recorded atmospheric) and the thunder, but at longer ranges direction finders are used.

The cathode ray direction finder for thunderstorm location [3] operates at about 10 kc/s and has two loop aerials, one in a north-south direction and the other east-west. The output voltages are amplified equally and applied to the two pairs of deflecting plates of a cathode ray tube. The arrival of an atmospheric from a particular direction is indicated by a momentary trace in a corresponding radial direction on the tube face.

The console of one of these direction finders is shown in Fig. 5. The top unit contains the twin amplifiers, with facilities for matching them exactly, the centre unit is the display, and the bottom unit contains the power supplies. Instruments of this type are in regular use at four stations in the United Kingdom, operated by the Meteorological Office, and have been adopted by several similar organizations in other countries. A considerable amount of information on the movement of thunderstorms is therefore available regularly for use in the study of the origins of radio noise.

Lightning Flash Counters

It has been seen that the distribution of noise over the world is related to the distribution of thunderstorms, and noise information has in fact been based partly on thunderstorm data derived from visual and aural observations by large numbers of people. There would be some advantage in having an automatic recorder which would count the number of lightning flashes within a given radius and several designs have been proposed. All of these instruments are simple low frequency receivers, and one particular design has been selected as suitable for tests at a large number of stations. The selected instrument consists of a vertical wire aerial connected to a wideband v.l.f. amplifying stage, followed by a multivibrator actuating a mechanical register. In general the number of flashes is read at hourly intervals.

Whistlers

Interesting results have emerged from a study of radio noise in the audio frequency band. This noise often contains whistles of descending pitch, known as whistling atmospherics or whistlers. It has been shown that these originate in lightning flashes which radiate impulses containing energy distributed over a wide band of frequencies, with a maximum in the audio frequency band. Current theories indicate that this energy travels through the ionosphere into

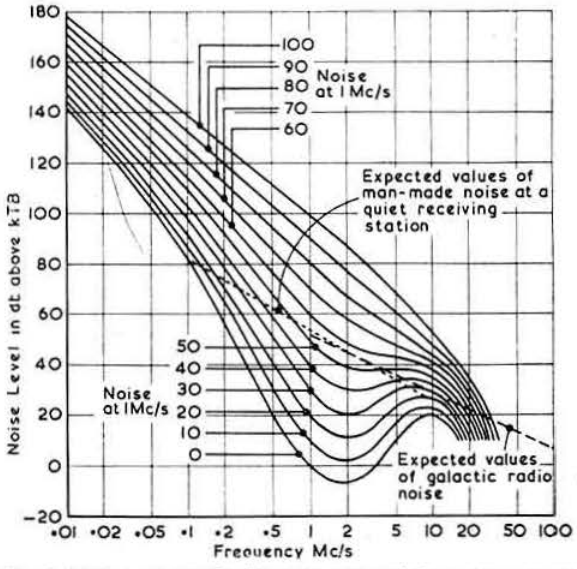

Fig. 3. Median values of radio noise expected for a short vertical aerial. For the times 08.00 to 12.00 and 12.00 to 16.00 (all seasons) and 04.00 to 08.00 and 16.00 to 20.00 (spring and summer).

the regions beyond, is guided along the earth's magnetic lines of force and returns to earth at a point in the opposite hemisphere. During this journey the higher frequencies travel at faster speed than the lower ones and arrive first at their destination, so the result is a whistle of descending pitch. Part of the energy may be reflected at the ground and travel back along the same path to the neighbourhood of the originating lightning flash, and by that time the frequencies are more spread out in time, giving a longer whistler. Several such reflections

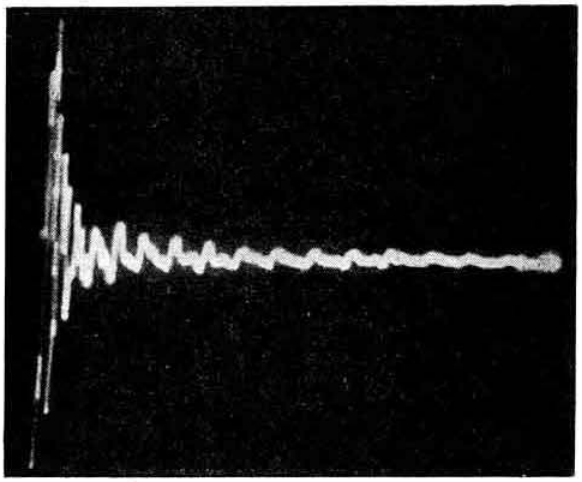

Fig. 4. Night-time echo type atmospheric.

may take place, the energy bouncing back and forth between the two hemispheres and taking the form of longer and longer whistlers. These observations show that there is appreciable density of free electrons at distances above the earth's surface of several times its radius.

Other types of audio frequency noise which are observed are more difficult to explain, but some are believed to result from the interaction of the earth's magnetic field with particles received from the sun.

Conclusion

To the communications engineer, atmospheric noise often causes interference and must be regarded as a nuisance. It has been shown, however, that it has useful properties. It can be used by meteorologists to locate thunderstorms and to study their electrical characteristics, and by research workers to investigate the properties of the ionosphere and the regions beyond. Even though noise has been widely studied since the earliest days of radio, it has many interesting features which are not yet explained.

Acknowledgments

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References

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[2] Crichlow, W. Q. " Noise Investigation at V.L.F. by the National Bureau of Standards," *Proc. Inst. Radio Engrs*, 1957, **45**, 778-782.

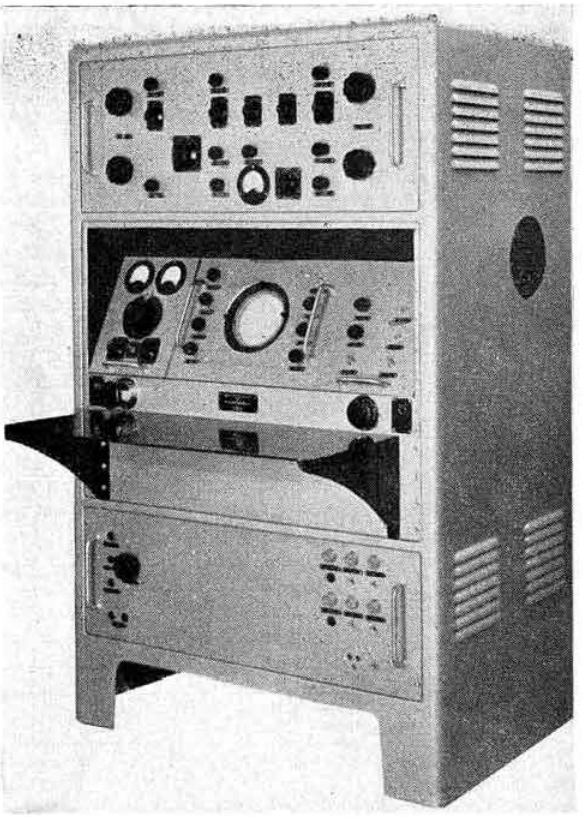
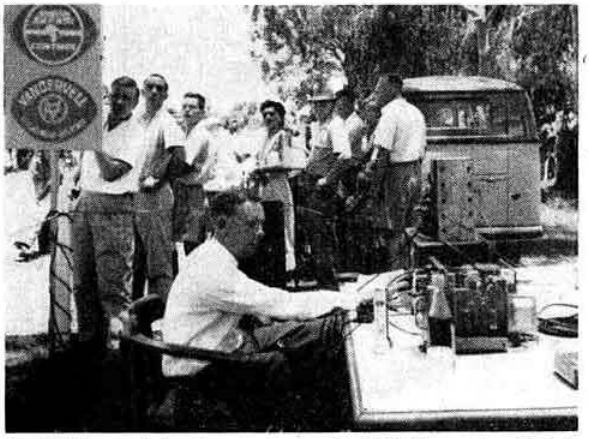


Fig. 5. Atmospheric direction finder. The height is 54 in., the width 36 in. and the depth 24 in.
(Photograph by courtesy of Rank-Cintel Ltd.).

[3] Clarke, C., and Harrison, V. A. W. "Low-Frequency Direction Finder," *Wireless Engineer*, 1955, **32**, 109-114.



VQ4CW/P at Kitale, Kenya, during the 1958 Coronation Safari. The equipment comprised a B2 transmitter modulated by 6V6s in class AB1, an Eddystone S.640 receiver and a 7 Mc/s dipole. This picture was taken by VQ4CW's XYL. *The Coronation Safari story is on page 285.*